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NAVAL RESEARCH

REVIEWS

NOVEMBER 1974

PROFILES IN SCIENCE

Mr. J. A. Pierce

Mr. J. A. Pierce worked at Harvard University from 1934 until his retirement this year, except during the World War II years. His early interests were in ionospheric wave propagation and in studies of sound reproduction from phonograph records which led to the development of long-playing and, later, stereo records.

During the war, he was at the M.I.T. Radiation Laboratory developing Loran. He became the head of Division 11 at that laboratory during the latter part of the war.

In 1946 he returned to Harvard to apply new techniques to radio research, which led to his proposals of the Radux and Omega aids to navigation. In the last twenty years, his research has been largely in development of the modern VLF methods for precise time and frequency dissemination, and in propagational studies in support of Omega. This work has been entirely supported through the Office of Naval Research.

Mr. Pierce holds a Presidential Certificate of Merit and various other awards, including a Certificate of Commendation from the Navy for his work on the Polaris Command Communication Committee.

Twenty-Five Years of Scientific Research Sponsored by the Joint Services Electronics Program at Harvard University

During World War II Congress set up the National Defense Research Committee with Dr. Vannevar Bush as Director. The intent was to establish war-time oriented research centers mostly in universities to aid the War and Navy Departments in the development of new equipments and military concepts. Three universities dominated the research in the field of electronics: The Radiation Laboratory at MIT under Dr. Lee DuBridge emphasized research in microwave radar, (2) the Harvard Laboratory under Dr. F. E. Terman specialized in countermeasures and electronic warfare, (3) the Columbia Laboratory under Dr. I. Rabi worked in the field of super-high frequencies. These three universities were the genesis of what was to be the Joint Services Electronics Program (JSEP).

The evolution of JSEP began in 1945 when the Department of Defense (DOD) named a committee of three—LtCol Zahl (Army), CDR E. R. Piore (Navy) and JAM John Marchetti (Air Force) at the war's end to close out the Radiation Laboratory at MIT. The Committee divided millions of dollars worth of equipment between DOD and university laboratories. Also some equipment was left at MIT which was kept in operation by a $600,000 a year contract for military research under the supervision of the committee. The committee left intact the smaller laboratories at Columbia and Harvard and negotiated contracts which converted their wartime efforts into long-range unclassified research of military interest.

Thus began the Joint Services Electronics Program in three universities, supported by three DOD contracts, and supervised by a committee representing the three services. The Office of Naval Research has always been responsible for the Navy's role in JSEP. Today the program has expanded to include nine universities with a budget of $5,500,000. To commemorate the 25th anniversary of JSEP last year, the following papers were presented as a brief historical review of the program at Harvard.

A Case History

N. Bloembergen

In 1946 the Joint Services Electronics Program evolved from the activities of the Radio Research Laboratory at Harvard University during World War II. One of the groups was involved with microwave tubes, magnetrons and klystrons, under the direction of Professor E. L. Chaffee, an authority in the theory of electron power tube design. It was becoming clear that further progress in microwave electronics would come from solid state devices and less from electron beams in vacuum. When I became a Junior Fellow at Harvard in January 1949, Professor Chaffee gave me hospitality in his microwave laboratory. My personal objective as a beginning scientist at the time was to learn something about microwave techniques. Since I was familiar with magnetic resonance phenomena in general, having earlier collaborated with Professor Purcell and Dr. R. V. Pound of Harvard in the first discovery of this now universally applied phenomenon, I started to work on ferromagnetic microwave resonance in metallic nickel near the Curie point. This topic had no immediately obvious connections with the Electronics Program at that time. A few years later, however, the importance of ferromagnetic resonance for microwave devices was well established. Professor C. L. Hogan joined the Program and started with Professor R. V. Jones a research project on ferromagnetic and ferroelectric materials. This program contributed a great deal to the development of microwave devices such as isolators, circulators, etc., which are widely used in radar and other microwave installations to date. Jones and Hogan developed an extensive materials laboratory for the production of ferrites for experimental purposes, and later for the newly discovered rare earth garnets having novel microwave properties.

My research on ferromagnetic resonance with Dr. R. W. Damon and Dr. S. Wang at high microwave power levels led to a distinction of three temperatures in a ferromagnetic material. The lattice temperature, the magnetic Zeeman temperature and the spin exchange temperature could assume different values in our experiments. These rather fundamental, but academic, physical concepts were augmented by research on nuclear magnetic resonance. Dr. A. G. Rodfield developed the concept of spin temperature in a rotating coordinate system in 1954. At the time these activities appeared to have little to do with electronics.

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*Dr. Bloembergen is the Gordon McKay Professor of Physics. His work has been mainly in the areas of nuclear and electronic resonance and nonlinear optics.

It turned out to be otherwise. In 1956 the concept of different temperatures in a magnetic spin system which, in the meanwhile, had been further developed theoretically by Ramsey and Purcell of Harvard, led me to the development of the multi-level solid state maser. The operation of such a device is similar to a heat engine, except that the different temperatures occur in the same volume of space. One part of magnetic energy levels is kept hot by a pump, another part is kept cold by interaction with the surroundings. The useful output is electromagnetic radiation. The solid state masers have proved useful as extremely low noise microwave receivers. Fourteen of them are used to detect weak signals in the big deep-space tracking network of NASA. They received the televised pictures of Mars, taken by the Mariners. They have also been used in the early warning radar system (DEW line), both on this continent and in Europe: They are also operating in the transatlantic satellite television communications link (Telstar), in the microwave receivers in Andover, Maine, and in England and France. They are also used in some telescopes for radioastronomy.

The same principle of the multi-level solid state masers applies to other frequency ranges of the electromagentic spectrum. In 1958 Drs. A. L. Schawlow and C. H. Townes, working under the support of another Joint Services Electronics Program at Columbia, made a detailed proposal as to how the principle could be used to make a new kind of light source with remarkable properties, the laser. Essentially all lasers use a pump mechanism of one kind or another to heat up some part of an energy level system, while another part is kept cool. It is a curious fact of nature that the same material, ruby, has been successfully used in both masers and lasers. The Cr^{3+} ions in this material have a suitable set of energy levels both in the microwave and in the optical region. The widespread development of laser applications during the past decade is well known. It is not universally appreciated that the early foundations were laid by the Joint Services Electronics Program at Columbia and Harvard Universities.

Some interesting features in the high power microwave experiments on ferromagnetic materials at Harvard mentioned above were interpreted by Professor H. Suhl, then at the Bell Telephone Laboratories, as a nonlinear parametric effect. This suggestion led to a great upsurge of proposals for microwave parametric devices. With the experimental realization of lasers in the early sixties the emphasis of the JSEP Program at Harvard shifted its attention to nonlinear parametric phenomena in optics. This was, of course, a logical development for our past interests and the essential unity of physical phenomena throughout the electromagnetic spectrum. The nonlinear

optical properties of matter, exposed to high intensity laser beams, are now a major subject of investigation, born in the Harvard program and elsewhere. This research is clearly relevant not only to high power laser systems being considered by the Department of Defense, but also to optical communications systems and to the burgeoning program of laser activated thermonuclear plasmas of the AEC.

The present basic research in nonlinear optics is, however, a far cry from the initial JSEP program concerned with electronic vacuum tubes. The development of the laser field, quantum optics and quantum electronics, would not be able to proceed as rapidly as it does at this time, if some of the basic scientific principles had not been established by early experiments on nuclear magnetic resonance, which looked like a rather academic pursuit some twenty years ago. The interaction of man and nature is largely determined by the forces between electrons and nuclei in atoms, molecules, fluids and crystals. Further study of the interaction of electrons in matter with electromagnetic fields remains a fresh source for future technology. This is a compelling reason for continuation of the Joint Services Electronics Program at academic institutions.

Research in Radio Wave Propagation and Aids to Navigation

J. A. Pierce

In contrast to the other programs that have been discussed this morning, I shall present an account of a research effort which, instead of repeatedly branching into new areas, has become more and more sharply focused as the years have gone by. The reasons for this kind of development can be explained, in somewhat personal terms, only by starting a dozen years before the beginning of the quarter-century which is being celebrated today.

From 1934 to 1941, then, I found myself being trained in the techniques of pulse sounding of the ionosphere under Professor Harry Mimno. Those were fascinating years, sharply punctuated by my being sent on ionospheric eclipse expeditions to the Soviet Union and the Union of South Africa. For our purposes this morning, these years were important only because they explain why I was, in 1941,

*Mr. Pierce, who recently retired, was Professor of Physics. He is renowned for his work in VLF methods for precise time and frequency dissemination, and in propagational studies in support of Omega.

drafted into a new group being formed in the Radiation Laboratory at M.I.T. This group was organized to exploit new ideas in radio navigation at very high frequencies, and it was hoped that my experience in pulse techniques and in the physics of the ionosphere might lead to extension of the service radius of this kind of system by operating in the medium- and high-frequency part of the radio spectrum. The results of early experiments were strongly in favor of the lower-frequency work, which rapidly developed into the Loran system. This quickly became the most generally useful of the new techniques for electronic navigation. It is still in very wide use today.

Toward the end of 1945, when termination was almost the only remaining activity of the Radiation Laboratory, it seemed to me that perhaps the Navy's Office of Reserach and Inventions, the predecessor of the Office of Naval Research, might be induced to support part of the Rad. Lab. group (preferably at Harvard) in an effort to apply the powerful new techniques, developed as part of the war effort, to scientific studies of the ionosphere. I therefore secured an appointment with Admiral Furer, the head of O.R.I., and went to Washington to discuss this idea. To my great surprise, I found Professor E. Leon Chaffee, who had become Director of Cruft Laboratory, also in Admiral Furer's office on much the same errand. Because Professor Chaffee's ideas were much more fully developed than my own, I am sure that my surprise was not shared by him or by the Admiral.

In any case, I soon was swept into Professor Chaffee's orbit, and at the beginning of 1946, found myself back at Harvard with a group of a dozen colleagues from the Radiation Laboratory, again in close association with Professor Mimno and preparing to use the new techniques for propagational research in the high-frequency region. Our main effort was in extension of exploration to transmission over long distances, as contrasted to the classical vertical pulse sounding. It must be said at once that these studies were not especially successful, primarily because the theory of ionospheric transmission turned out to be more accurate than we had expected, so that our results could be predicted nearly as well as they could be measured. The work continued for a number of years, however, generally in the form of research toward doctoral theses.

An abiding interest in radio navigation remained, of course, with the group. After much thought, and some theoretical studies of the interference to be expected in ionospheric transmission, it was deduced that the uncertainties in the time of transmission of a suitable radio signal are primarily a function of the height of a reflecting layer

and are not too strongly affected by the kind of signal. In simple words, a train of sinusoidal signals of low frequency might, within certain limits, be measurable with nearly the precision of a train of pulses. These ideas led, in 1947, to the proposal of Radux, a navigation aid in which the distance-measuring function was to be performed upon a train of 200 Hz cycles modulated upon a low-frequency carrier. After thorough study, the idea was adopted by the Navy, which began development of an experimental system in 1950. This work was carried forward primarily at the Navy Electronics Laboratory in San Diego, with help from the Naval Research Laboratory and other institutions, including as much as could be provided from Harvard under the military security classification which then prevailed. These efforts were continued throughout the 1950's. They failed to lead to an operating system, largely because Loran and other short-range systems had given navigators a taste for higher accuracy than Radux could provide.

In 1953, Dr. Louis Essen, of the National Physical Laboratory in Great Britain, visited Harvard and told of a new 60 kHz standard-frequency signal being transmitted in England. Although it had been intended only for local use, we found that the signal could be measured at Harvard with excellent accuracy—100 to 1000 times the precision of high-frequency signals. This discovery, with the active collaboration of Dr. Essen and Mr. H. T. Mitchell of the British Post Office, led to the frequency stabilization of the very-low-frequency communication station at Rugby and a series of measurements at Harvard that lasted fruitfully for more than an 11-year cycle of solar activity. It is an interesting sidelight that for two or three years Harvard found itself in the curious position of being the only reference point for high-precision intercomparisons between the time-and-frequency system of the Greenwich Observatory and that of the U.S. Naval Observatory and the Bureau of Standards. These two systems were operated under quite different philosophies in those days, as the British tried to smooth out the annual variation in the speed of rotation of the earth, while the Americans did not. Today, of course, this method of frequency intercomparison has become standard and is widely used, while, perhaps in part as a result of our efforts, the British and American time systems are maintained in a very high degree of coherence.

These precision measurements made possible, in 1955, our serious proposal to the Joint Services of a navigation aid to operate in the very-low frequencies. We soon named this system Omega. Work on it was added to the Radux efforts at the Naval laboratories and, of

course, at Harvard, where it was a great help to find the security classification soon removed. It rapidly became clear that these lower-frequency studies were much more promising, and the Radux work was gradually abandoned. Radux had had, however, a profoundly important influence through forcing the Navy to develop an internal expertise in low-frequency propagation and in the somewhat-tricky techniques of phase measurement.

At Harvard, from 1960 to 1965, our propagational studies became concentrated almost entirely in support of Omega. With low-power transmissions made by the Navy from borrowed antennas at various places between Hawaii and Wales, Cambridge was at an advantageous location for observation. We made the first analytical models (based largely upon the Rugby data) leading to successful prediction of diurnal and annual variations in the time of transit of signals; first solved the problem of measuring the velocity of propagation in spite of a complex system of ambiguities; and first measured the variations in velocity that depend upon soil conductivity and direction of propagation with respect to the earth's magnetic field. We also, by a process which we were later to recognize as times series modeling, established a satisfactory method for controlling the times at which signals were emitted from a group of stations, so that their transmissions could be brought into precise synchronism, whatever the locations of the stations.

In the middle 1960's, most of this work was done to clarify and focus the work of the Omega Implementation Committee, a small group of non-Navy experts, assembled and supported by the Bureau of Ships, to specify the characteristics of the proposed system. The reports of this committee, which had the writer as chairman, form the technical foundation of the present and future Omega system.

It might be remarked that the slow development of Omega is, at least in part, a result of supposed competition. It was necessary to wait out two eras in which many people claimed that the navigational problems of the future would be solved by inertial navigation or, alternatively, by satellites. Only after time had revealed the generally prohibitive costs and other limitations of these methods was it possible to attract substantial financial support for Omega. In any case, Omega received interim operational status in 1966, together with the commitment of funds for the full-scale, full-powered network of stations, and the Navy's construction efforts were transferred to a Project Management Office in the Materiel Command.

Since 1966, the work at Harvard has involved itself chiefly with studies of the high correlation between Omega signals at various

frequencies. These studies have revealed ways in which the pernicious effects of propagational anomalies (a former source of worry to many critics) can be reduced to nearly zero, while the general accuracy is improved by perhaps a factor of two. Within the past year a reasonably satisfactory way of "correcting" observed data has been derived. This technique is based upon using the difference between observed and predicted dispersion to modify measured values at the individual frequencies. This technique can be used to avoid ambiguities and the effects of anomalies and to achieve a minimum error at any chosen frequency. Rather remarkably, it also offers some compensation of errors of prediction which heretofore have been the dominant errors of Omega.

It is fortunate for the future of Omega that these discoveries can presumably be disseminated and introduced into the operating system before the next maximum of solar activity. In the present minimum, propagational anomalies are small and infrequent and Omega behaves well without requiring much effort or understanding on the part of receiver designers and operators. With full worldwide operation expected in another two or three years, it has been one of the writer's worries that people first using the new system as the solar activity reaches its maximum might have some severe disappointments. The new discoveries are very likely to prevent this, as it is gratifying to observe that the many potential manufacturers who come to discuss these matters show an intelligent interest and a strong desire to adopt the best techniques.

It remains to express my very sincere gratitude to the Joint Services, acting through their various scientific offices, for providing patient and encouraging support through both the more-productive and the less-rewarding years. For my own part, I shall feel satisfied with the chief among many minor contributions I have been able to make during half a lifetime spent in pursuit of better navigation. I find Omega to be a system which combines the primitive virtues of worldwide and continuous coverage with excellent reliability, an accuracy which I believe will soon be defined by root-mean-square errors of not more than a half-mile, and an economy of operation that has not been approached in the history of modern navigational techniques. It will, I am convinced, be a primary method, not only for navigation but for many other related purposes, for at least a number of decades. I hope that the knowledge of your contributions toward this fraction of Harvard's effort will, in the years to come, give you and your Services equivalent satisfaction.

A Brief Review of Research in Electromagnetic Radiation

R. W. P. King

Introduction

Since 1946 the Defense Department has supported a continuing program of research at Harvard on the applications of electromagnetic theory to practical problems in *communications, telemetry, diagnostics,* and *hazards*. Advanced theoretical and experimental techniques have been developed and applied to obtain a solid foundation of useful information in a form that is simple, complete, and accurate. The combination of analytical, numerical, physical, and experimental methods has proved to be singularly effective in solving complicated problems, building a permanent foundation of knowledge, and providing an education for prospective scientists and engineers that is so broadly based that they can work effectively in many fields.

Antennas

Antennas are the eyes and ears of our technological age. Without them radio, television, and radar would be impossible. They are indispensable elements in the guidance systems of spacecraft and rockets; they are the telescopes of radio astronomy; they transmit and receive telemetered information from miniature circuits implanted in living bodies. Antennas have many shapes and sizes each with its own properties that make it useful for a particular application. Research at Harvard has been directed toward determining these properties and developing antennas with new ones.

The basic radiating elements are the *dipole* (monopole over a conducting plane), the *loop*, and the *slot*. Each of these may have a variety of shapes and sizes relative to the operating wavelength and they may be combined in many ways to form *directive arrays*. Comprehensive studies of all of these have been made at Harvard. These have not been limited to idealized models but have been concerned especially with actual antennas driven by practical transmission lines.

The dipole antenna has been investigated especially in its *biconical* and *cylindrical* forms. A study of the former when provided with a

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*Dr. King is Professor of Applied Physics. His fields of interest are electromagnetic theory, radiation and antennas, and microwave circuits.

central sphere has given complete information on the transmitting and receiving properties of a satellite with antenna. Practical theories of electrically-thin cylindrical antennas of any length have been provided and verified both for symmetrically and asymmetrically driven and loaded elements. The properties of very long antennas are needed in determining the responses of antennas when excited by pulses. Important contributions to the transient behavior of monopoles have also been made. From a study of the resistive cylindrical antenna has come a unique frequency-independent, directional antenna that has application to communicating by trains of pulses. Theoretical and experimental techniques were extended to electrically-thick cylindrical antennas such as the periscope tube of a submarine; the glass-filled tube was also treated.

Paralleling the study of dipoles, an exhaustive investigation has been made of *circular loops* ranging in size from the electrically very small to the large when driven or loaded at one or at many points. The *square loop* has also been analyzed including a related *corner-reflector* antenna. Loop antennas have important applications in blind landing systems, direction finders, and guidance circuits for rockets. A special study on electrically very small loops for the last-named purpose has been completed. The theory of the shielded loop antenna was developed and applied to determining errors in direction finders and in magnetic-field probes. The theory of *folded antennas,* an important type related to loops, dipoles, and transmission lines, was formulated at Harvard.

For applications requiring antennas that do not protrude from a metal surface, as for aircraft and rockets, the *slot antenna* is useful. The complementary relations obtaining between slots and dipoles were developed completely including the feeding transmission line. This led to the development of the slot transmission line. Arrays of slots and slots on curved surfaces were also studied. The relation between open slots and cavity-backed slots is under study.

Arrays of Cylindrical Dipoles

For point-to-point communication directive and beam-scanning, antennas are required. Such antennas with many different properties can be obtained by suitably arranging a small or very large number of dipoles in an array. This involves the complicated problem of mutual coupling. A major contribution from the researches at Harvard has been the formulation of a new and complete theory of dipole arrays that for the first time takes full account of all effects of interaction among the currents in the elements. This theory has been applied to

curtain arrays of driven and parasitic elements; arrays with unequal elements like the Yagi and the frequency-independent log-periodic antenna; collinear, planar, and three-dimensional arrays; and to phased arrays. Complete experimental checks have been provided. A new theory of coupled electrically-long antennas has been developed as a first step in the study of the response of arrays to pulses. Coupled electrically thick antennas such as occur in structurally rigid microwave antennas have been investigated.

Antennas and Probes in Dissipative Media and Plasmas

When an antenna is immersed in the earth, the sea, the arctic ice, the ionosphere, or a living organism, its properties are greatly affected by the surrounding medium if it is bare. Its behavior is quite different when it is insulated. A complete theory of bare antennas in arbitrary homogeneous media including cold plasmas has been developed and verified experimentally. A similar study on insulated antennas is in progress. Both dipoles and loops are included. When the medium is not homogeneous or isotropic further problems arise. A broad generalization of the existing theory of dipoles near the interface between the sea or the earth and the air above it has been made and applied to develop a novel directional antenna specifically for subsurface communication in the ocean. Further studies involving other media are in progress. A unique and powerful experimental method for studying the properties of inhomogeneous media by means of an agar-agar chamber has been developed and applied to model the earth's crust. This method could be applied, for example, to study subsurface and earth-ionosphere communication with submarines using a buried antenna.

Scattering and Diffraction

The return signal received by a radar is scattered from the target. It depends on the shape and size of the obstacle and on the material from which it is made. Extensive new theoretical and experimental techniques have been developed for determining the fields scattered by various obstacles. These include the first and only theoretical determination of the scattering from a cylinder of *finite* length. The scattering cross sections of arbitrary spheres of homogeneous materials including water and plasmas have been determined. Fundamental investigations on the reflection of electromagnetic waves from sound waves were carried out in conjunction with a problem in submarine detection by electromagnetic means.

Shielding and Radio-Frequency Hazards

The problem of shielding against large electromagnetic pulses is of current interest. It was also of interest when the inner conductors of long shielded cables leading from the site of a nuclear explosion in the Nevada desert to the observation point melted. Extensive work on shielding against transients was carried out including shielding by metal sheets, by the earth, and by cylinders of finite length. It was in this last-named work that external and internal resonances were shown to yield sufficiently large currents in the interior of the shield to melt the inner conductor.

When rockets are on the launch-pad, external electromagnetic fields may induce currents on cables coupled to the rocket or in the internal circuitry through openings where access covers have been removed. Theoretical investigations of the magnitudes of such currents have been made.

Conclusion and Prospect

The many advances that have been made in the application of electromagnetic theory to practical problems have been reported in 346 technical and scientific reports and in an even larger number of published papers. They are summarized in seven books. Because the researches have been systematic and coordinated, they have laid a strong foundation for continuing progress in many new and challenging fields. These include the following:

1. The properties of antennas and electromagnetic waves in dissipative, layered and stratified media; subsurface communication; geophysical exploration; antennas in plasmas and plasma diagnostics using electromagnetic probes.
2. Time-domain problems that involve radiating elements, arrays, and electromagnetic pulse propagation; transients and pulses in communications and diagnostics.
3. Field pattern synthesis using arrays of antennas and the newly developed theory of arrays. This provides great time-saving over numerical methods.
4. Electromagnetic hazards and pollution; shielding against undesired radiation. Heart pacemakers and phrenic nerve stimulators can be interrupted by electromagnetic radiation; electromagnetic pollution will be greatly increased when automobiles have radars to avoid collisions.

5. Biomedical applications of antennas, steady-state and pulsed electromagnetic fields; implanted transmitting and receiving antennas and probes for use in telemetry, pacemakers, stimulators, etc.; thermal and structural effects of electromagnetic radiation on living tissue; effects of internal resonances.

Largest Balloon Launched by ONR

The world's largest unmanned balloon was successfully flown on August 5 from Fort Churchill, Manitoba, Canada, on the shores of the Hudson Bay. The balloon carried an 800-lb scientific payload to 155,000 feet altitude. When fully inflated, the balloon had a volume of 50.3 million cubic feet and a diameter of almost one tenth of a mile.

The flight was sponsored by ONR and the Office of Space Science of the National Aeronautics and Space Administration using the facilities of the Navy SKYHOOK program. SKYHOOK, under the auspices of ONR, is the oldest active scientific balloon program.

The purpose of the flight was to lift an instrument package for a scientific experiment conceived by Dr. R. C. Hartman of NASA's Goddard Space Flight Center. The 800-lb package contained a magnet, spark chamber and counter system to measure positron and electron spectra between 20 and 800 MeV at the 1.2 millibar level (approximately 155,000 feet altitude).

The balloon, fabricated by Winzen Research, Inc., of St. Paul, Minnesota, was made of half-mil polyethylene film, weighed 1 1/2 tons, and was 703 feet long. The entire flight train (balloon, experiment package, and parachute) was 835 feet long and weighed 4,300 pounds.

Launching of the mammoth, helium-filled balloon was made at Fort Churchill by the flight operations crew of Raven Industries, Inc., of Sioux Falls, South Dakota. Each year the SKYHOOK project launches high altitude scientific balloons from Fort Churchill with the cooperation of the National Research Council of Canada.

As the balloon rose over the Hudson Bay to its float altitude of 155,000 feet, it assumed its fully inflated form of 512 feet in diameter and moved westward approximately 500 miles toward Lake Athabasca. The balloon was tracked by the Project SKYHOOK DC-3 aircraft.

After 18 hours at float altitude, the balloon was brought to a lower and denser height by allowing some of the helium to escape. At 100,000 feet, where the atmosphere is dense enough to support a parachute descent, the scientific package and parachute were separated from the balloon by radio command. This same action also split the balloon from top to bottom allowing the helium to escape and the balloon material to descend to earth thus removing any hazard to air navigation.

Thunderstorm Research and Sferics Observations

H. W. Hiser
University of Miami

Introduction

When lightning occurs, either between cloud and ground or between two different charge centers in a cloud, radio frequency noise is generated and can be detected with an ordinary AM radio. This radio frequency noise generated in the atmosphere is called sferics. By measuring the direction of arrival of sferics with radio direction finding equipment, it is possible to determine the direction to the thunderstorm source. The objective of the research described here and which is supported by the Office of Naval Research and conducted at the University of Miami is to evolve some forecasting tools for thunderstorm formation and development using a radar and a directional sferics indicator.

During the early and mid-1960s, Douglas A. Kohl of Litton Industries developed under an Office of Naval Research contract a 500 kiloHertz system, with a 15 kiloHertz bandwidth, based upon this principle for locating thunderstorms or electrical discharges in convective clouds approaching thunderstorm stage of development. He found that the use of 500 kHz as a monitor frequency was an excellent compromise between sensitivity and practical detection ranges. The sferics source–propagation conditions existing at this frequency result in a detection range comparable to meteorological radars. Also, the 500 kHz is a "guarded" international distress frequency which minimizes interference from man-made transmissions.

The system described here was called SPARSA/S (Sferics Pulse Azimuth, Rate and Spectrum Analyzer, model S) and was developed by Kohl for use by the Air Force Eastern Test Range (AFETR) at Patrick Air Force Base, Florida. It is thresholded for a maximum detection range of approximately 200 nautical miles which is similar to the maximum range of a meteorological radar. It divides the azimuth circle into 64 sectors, 5.6° wide to provide 64 channels for

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360° coverage. The polarization of atmospheric noise at 500 kHz is predominantly vertical. This is made use of by a Directional Sense Unit attached to the SPARSA/S which separates "front" and "back" sferics signals to provide positive identification of direction of arrival.

The electrical output of the SPARSA/S is a parallel data output, i.e., there is an electrical terminal for each of the 64 azimuth sectors. The average sferics pulse count rate in an azimuth sector appears at the output terminal as a proportional voltage (0-20 volts) from a storage capacitor which is in analog form and continuously updated. Data from the 64 sector storage capacitors may be displayed or processed in either parallel or serial form through high input impedance (100 megohms) data interrogation equipment. The crossed-loop directional antennas are programmed to mechanically shift orientation so that each of the 64 sectors is surveilled for 10 seconds beginning every 110 seconds. In a 10 second period 8 sectors are scanned. Since there are 64 sectors, the scanning operation is completed in 80 seconds. The 30 seconds difference between 80 and 110 seconds is the time needed to return to the starting point.

Sferics pulse amplitudes decrease with increasing range R as $1/R^a$, where a lies between a value of 1 and 2. The Litton SPARSA/S sensor contains a form of range normalization through the use of an automatic variable threshold in the sferics count-rate circuit. The level of this threshold for each sector increases as the range to the storm decreases and is a function of the average of the peak sferics pulse amplitude $[\hat{E}]$ for the sector. Starting at zero pulse count rate, all new pulses from a sector are counted. As the pulse count rate increases to about 60 pulses per minute, the threshold fraction increases to $\hat{E}/4$ and remains at this level for all higher count rates. The $\hat{E}$ value for each sector is stored on a capacitor and updated during a 10-sec sampling period once every 110 sec. This is the same sequence of sampling employed to update the 64 sector readout capacitors. During a 10-sec sampling period, all pulses are accepted which originate in the eight azimuth sectors under surveillance and which exceed the eight threshold levels ($\hat{E}/4$ for count rates >60 pulses per minute) for the respective azimuth sectors. If two or more storms of approximately equal intensity exist in a given azimuth sector, the closest storm will determine $\hat{E}$ and the resulting counting threshold may be too high to detect the other storms if they are at considerably greater distances. Likewise, a local storm at the SPARSA/S station can result in a high $\hat{E}$ value and thereby diminish the indicated sferics activity from more distant locations.

University of Miami Sferics and Radar System

The original SPARSA system at the AFETR consisted of a three-station network taking cross bearings and employed a rather complex centralized display system at Patrick AFB. The Radar Meteorological Laboratory, RML (now the Remote Sensing Laboratory) of the University of Miami developed a single station system coupled directly to a meteorological radar so that both the sferics vectors and the radar data are displayed on a single cathode ray tube of the plan position indicator (PPI) type (1). This system was developed under sponsorship of the Office of Naval Research to conduct studies of thunderstorms in the south Florida area. After successful tests, a duplicate system was built under a Naval Air Systems Command contract and delivered, in 1971, to the Fleet Weather Facility at Jacksonville Naval Air Station, Florida, for use with their AN/FPS-106 meteorological radar.

Figure 1 shows the SPARSA/S sensor housed in a roof-mounted, air-conditioned radome at the University of Miami. An important

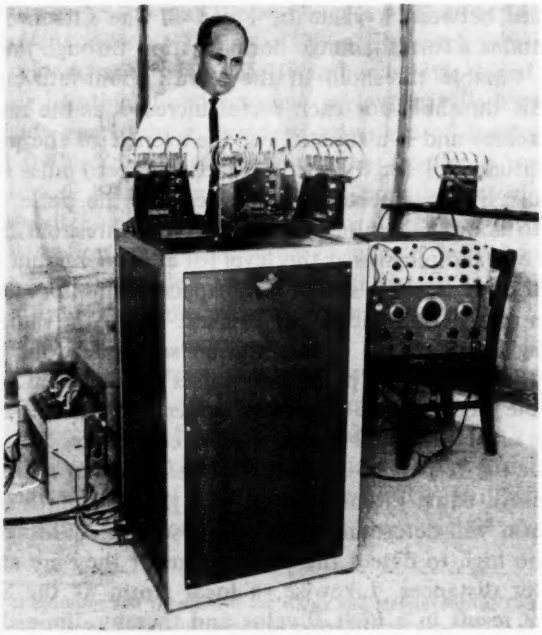

Figure 1—Litton 500-kHz SPARSA/S sferics sensor housed in radome.

aspect of the SPARSA/S is its small size and weight (23 X 23 X 52 inches and 140 pounds). Figure 2 presents a functional diagram of the radar and sferics display system developed by George Andrews at the RML. The parallel-to-serial commutator of the sferics-to-radar data converter is installed on the floor of the radome. This unit sequentially interrogates the 64 memory capacitors of the SPARSA/S as the meteorological radar antenna rotates in azimuth. Another *chasis* of the data converter containing the analog voltage-to-time converter, sferics video flip-flop, control gating, and time-share logic assemblies is installed in the radar room near the PPI displays. Thus, there is only one cable taking antenna azimuth information from the radar to the sferics sensor shelter and one bringing back sferics data to the radar.

As the radar antenna scans in azimuth, the 64 sector storage capacitors of the SPARSA/S are sequentially interrogated and their stored voltages are presented as vectors radiating from the center of the PPI scope at the proper azimuths. The radar video is blanked out to about 25 miles radius and the SPARSA sferics vectors are inserted in its place. Figure 3 is a time-lapse photograph of the UM/10-cm radar PPI scope with intensity contoured precipitation echoes and sferics vectors pointing to some of them. Three intensity contours are presented in this photograph. The outer boundaries of all echoes represent the range-normalized minimum detectable rainfall intensity for

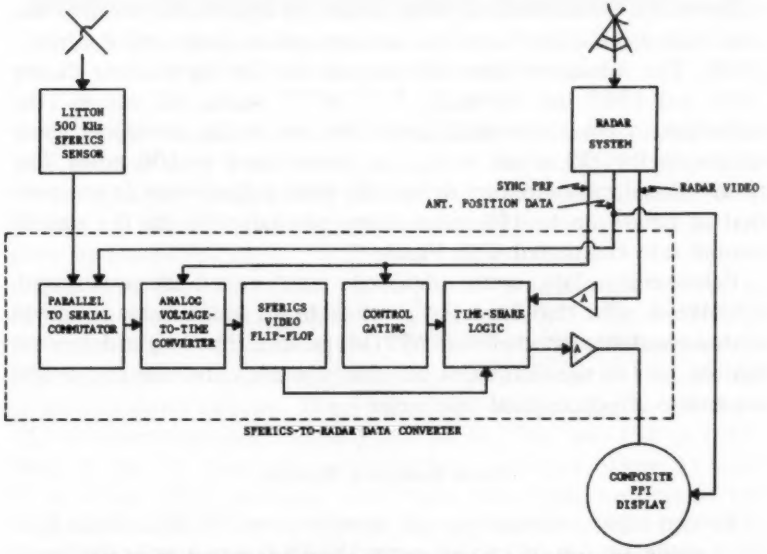

Figure 2–System functional diagram–radar and sferics display.

this radar, 0.1 mm/hr or greater, the dark holes are the second level of intensity, 2.3 mm/hr or greater, and the small bright white cores within the dark regions are the most intense, 23 mm/hr or greater. A fourth contour of 60 mm/hr or greater, which would be a dark hole in a bright white core, is not shown in this photograph. The vector lengths in Figure 3 show the relative amounts of sferics activity from the echoes at this time. The length of a vector is a function of both amplitude and rate of occurrence of sferics in its 5.6° sector. They grow in length and then shrink as a thunderstorm goes through its life cycle. By analyzing a time-lapse sequence of these photographs the growth and decay and life span of a thunderstorm can be studied.

A second time-lapse camera photographed another scope on 100 miles range without sferics vectors. This provided research data on precipitation echoes near the station. In an operational application, visual observations can be made of activity near the station or the SPARSA/S display can be turned off for a few minutes while the radar operator takes notes of precipitation echoes near the station. The SPARSA/S detects discharges up to an elevation angle of +45° but the accuracy of the system decreases at near ranges of 5 miles or less.

The University of Miami's 10-cm wavelength radar (UN/10-cm) to which the SPARSA/S was coupled, has a conical beam 2° in aperture and was operated with the axis of the beam tilted 0.5° above the horizontal. The peak transmitted power was approximately 450 kilowatts with a 2-microsecond pulse length. A logarithmic receiver was used with a multi-level isoecho contour system (Senn and Andrews, 1968). The minimum discernible signal for the log receiver during 1968 and 1969 was normally 3×10^{-14} watts. All echoes (the reflection of the radar signal from the rain in the cloud) at lesser ranges on the PPI scope were range normalized to 100 miles. The range-normalized minimum detectable radar reflectivity (Z) was such that at ranges up to 100 miles it was equivalent to the 0.1 mm/hr rainfall rate mentioned with Figure 3.

Echo-height data were obtained with a 4.6-cm wavelength AN/MPS-4 radar that has a 0.8° vertical beam-width and is equipped with a constant altitude PPI (CAPPI)-type scan. The height data were limited to 100 nautical miles because of earth curvature and height resolution effects beyond that range.

Some Research Results

Several other investigations of thunderstorm 500 kHz sferics have been made by use of one or more SPARSA sensor units similar to

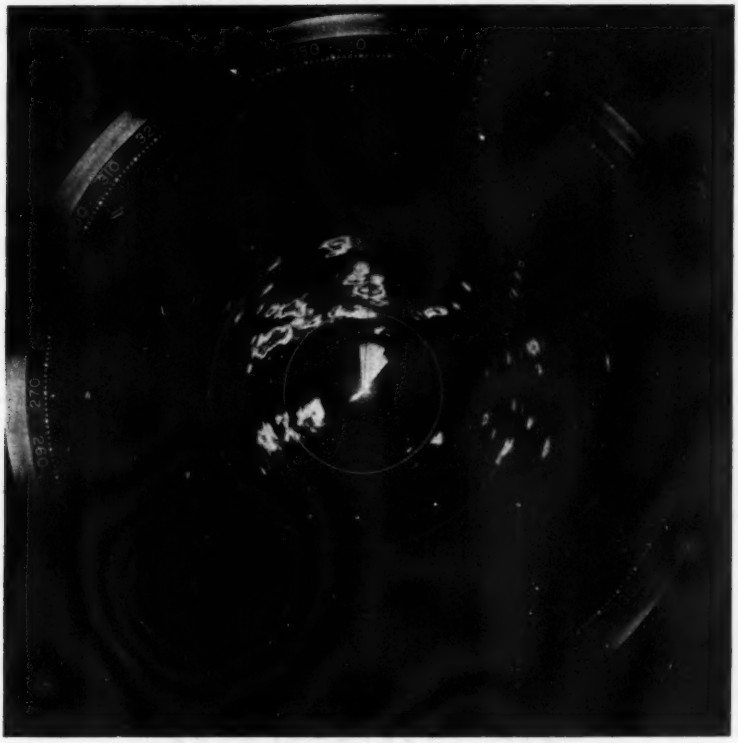

Figure 3–SPARSA vectors displayed at center of PPI scope with contoured precipitation echoes. Range circles are 50 n mi each.

ours, but the readouts were more difficult to compare with radar data because they were not displayed on the radar PPI scopes together with the precipitation echoes. Some of these include (3-9). Results of research with the system at the University of Miami are given by Hiser (10-12).

Relations between sferics activity and precipitation echoes as shown on the UM/10-cm radar are given in Table 1. The increase in the number of vectors from 1967-69 merely reflects an increase in the amount of data gathered rather than any change in the amount of thunderstorm activity. The 1450 sferics vector cases occurred on 232 thunderstorm days: 22 in 1967, 79 in 1968, and 131 in 1969. Most of the 75 cases of vectors without echoes (column 1) were weak vectors which probably came from thunderstorms beyond the range of the radar. A very high percentage of the vectors that were associated with echoes within 200 nautical mile range (column 2)

Table 1

Relations between life cycles of SPARSA vectors* and precipitation echoes on 10-cm radar within 200 n mi of Miami during the summers of 1967, 1968 and 1969.

	(1) Vector but echo never appeared	(2) Vector with echo at some time (3+4+5)	(3) Vector with single cell or contoured core in echo area	(4) Vector with amorphous echo (R<100 mi)	(5) Vector with amorphous echo (R>100 mi)	(6) Vector appeared before echo	(7) Vector continued after echo	(8) Vector grew as echo grew or intensified	(9) Growth of echo and vector not correlated
1967	4	82	59	7	16	0	0	49	33
1968	0	360	360	0	0	0	0	261	99
1969	71	933	921	12	0	37	46	888	45
Total	75	1375	1340	19	16	37	46	1198	177

*Vector in this table defined as the primary 5.6° SPARSA vector pointing to a center of sferics activity. Usually there were smaller adjacent vectors associated with these primary vectors. Life spans of primary vectors were from several minutes to an hour or more. A total of 1450 vectors were analyzed.

correlated with single isolated echo cells or with contoured cores of more intense activity within a large echo area (column 3).

The vectors associated with fairly weak amorphous echoes at ranges $\leqslant$100 mi indicate electrical activity without the presence of intense precipitation or well-developed cells. However, the same cannot be said for all of the vectors associated with echoes of this type at ranges considerably greater than 100 mi. Some of the echoes at extended ranges in this category may represent tops of intense precipitation echoes that lie mostly below the radar horizon.

Most centers of sferics activity were identified by one 5.6° primary vector plus some less intense vectors on each side of the primary. There were usually from one to four or five adjacent vectors associated with a center of activity, depending upon its size and range from the station. The intensities of 1032 primary vectors in July 1968 and May through September, 1969, were classified as weak, moderate or strong according to their magnitudes. These are relative classifications. The strong category was based upon maxima observed with intense sferics activity, and the other two classes were scaled down from this. Sixty-eight percent were weak, 17% moderate, and 15% strong.

The intensities of all precipitation echoes associated with sferics vectors were tabulated. However, echo intensities become distorted at extended ranges beyond about 100 mi and are not comparable to those at lesser ranges. For this reason, the data in Table 2 are limited to sferics vectors associated with precipitaton echoes within 100 nautical miles on the UM/10-cm radar. The percentages of weak, moderate and strong sferics vectors associated with each of the four available echo intensity contours are shown in this table. Range-normalized echo intensity contour 1 represents $Z \geqslant 10$, contour 2, $Z \geqslant 10^3$, contour 3, $Z \geqslant 2.5 \times 10^4$, and contour 4, $Z \geqslant 10^5\,mm^6\,m^{-3}$ at ranges up to 100 mi. These radar reflectivities (Z) are based upon the Rayleigh scattering law and are equal to the sum of the sixth powers

Table 2

Intensity of 790 sferics vectors vs intensity of associated precipitation echoes within 100 mi on UM/10-cm radar, May-September, 1969.

538 weak sferics vectors Echo intensity*				126 moderate sferics vectors Echo intensity*				126 strong sferics vectors Echo intensity*			
1	2	3	4	1	2	3	4	1	2	3	4
52%	31%	16%	01%	29%	37%	32%	02%	17%	43%	37%	03%

*Contour values: 1. $Z \geqslant 10$; 2. $Z \geqslant 10^3$; 3. $Z \geqslant 2.5 \times 10^4$; 4. $Z \geqslant 10^5$ mm^6 m^{-3}.

of the water drop diameters per cubic meter of the storm surveilled by the radar. A transform equation was used to convert the Z valves for each contour to the rainfall rates in mm/hr that were presented with Figure 3.

As one might expect, Table 2 shows that weak sferics activity tends to be most frequently associated with weak echoes on the radar and moderate and strong sferics activity with more intense radar echoes. However, moderate and strong sferics activity also are shown to be associated with weak precipitation echoes within 100 miles range. This can be operationally significant to weather forecasters and flight controllers.

The life spans of the primary vectors associated with centers of sferics activity were tabulated for July 1968 and all of the 1969 data. Forty-nine percent of 1103 cases had life spans less than 1 hour; 22% between 1-2 hours; 13% between 2-3 hours; and 8% between 3-4 hours. The few cases with longer histories were probably from multiple adjacent centers that regenerated, thereby preserving the SPARSA vectors. In fact, most of the centers of sferics activity that lasted much more than one hour apparently were associated with multicellular thunderstorms as discussed in the report of the thunderstorm project (Byers and Braham, 1949).

The heights of echoes associated with sferics vectors were tabulated for July 1968 and all of 1969 as observed within 100 mi on the MPS-4 radar. Because of the high antenna tilt angles required, echo tops at ranges less than 20 miles usually could not be measured. Table 3 gives both the numbers of echoes and percentages of all echoes measured that reached each height interval. The visible cloud tops would be somewhat higher than the radar tops. Perhaps these radar tops appear too low. However, they agree favorably with earlier echo height measurements in South Florida (Hiser and Adt, 1961). Also, some of those with tops below 20,000 ft probably originated as warm cloud thunderstorms of the type reported by several investigators and discussed by Chalmers (1967). Sometimes sferics occurred when all of the radar detectable echo was below the freezing level.

Table 3

Height of tops of 497 echoes, $R \leq 100$ n mi, associated with sferics vectors, July 1968 and May-September, 1969.

	Height (ft)					
	<20,000	20-29,000	30-39,000	40-49,000	50-59,000	>60,000
Number	120	196	120	52	8	1
Percent	(24%)	(39%)	(24%)	(11%)	(02%)	

Conclusions

The research results and experience with the equipment indicate that a directional sferics sensor coupled to the display of a meteorological radar should be most useful to the forecaster for both airborne and surface operational requirements. The radar maps the precipitation areas while the sferics vectors point to the thunderstorms within it and indicate the magnitude and time changes of electrical activity.

Although weak sferics activity tends to be most frequently associated with weak echoes on radar, the research data within 100 miles range show that large reflectivity (Z) values and/or high-altitude echo tops are not required in order to obtain moderate or strong sferics activity in southern Florida. Also, some of the echo height data gave strong indications of warm cloud sferics at least in the onset. These conditions are theoretically more likely to exist at low latitudes than in the mid and high latitudes but the sferics equipment is needed to give positive answers for operational applications. Radar meteorologists generally assume that tall, intense precipitation echoes are thunderstorms. The sferics equipment shows that at least in low latitudes these conditions are not required.

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New Commanding Officer of Naval Arctic Research Laboratory

Lieutenant Commander Brian Shoemaker, USN, has assumed the post of Commanding Officer of the Naval Arctic Research Laboratory, relieving CDR Robert B. Bernhardt, USN, who was transferred to Commander in Chief Alaska. LCDR Shoemaker, 37, whose home is Bishop, California, took command of the Naval Arctic Research Laboratory on 30 September. He was previously the operations officer of HSL-33, the Navy's first operational Light Airborne Multi-Purpose System (LAMPS) squadron.

As the Commanding Officer, LCDR Shoemaker will supervise the activities of the Naval Arctic Research Program including the following: provision of expert guidance to and coordination of field and laboratory research tasks assigned by the Chief of Naval Research; logistic support for all Arctic Research Programs; indoctrination and training of administrative and scientific personnel for living and working in arctic areas; development of techniques, methods and procedures for exploitation of arctic research; liaison between ONR personnel and scientists in the arctic; and advisory functions to Chief of Naval Research on current programs and requirements for future research.

LCDR Shoemaker, who received his BA degree in geography in 1960 at the University of California, has been closely associated with polar research and anti-submarine warfare throughout his career. He has served tours of duty with HS-3, VX-6, HS-1, HC-5, HSL-31 as well as HSL-33. He "wintered-over" in Operation Deep Freeze in 1967 where he flew the last mid-winter helicopter flights in Antarctica. In 1970, he was flown onto the sea ice in the Beaufort Sea where he and four Eskimos built ARLIS V, a sea ice station which served as a platform for scientific research. In 1971, he spent a month on Fletchers Ice Island, an iceberg station, at 86° N conducting underwater sound studies in the Arctic Ocean; this data was the basis for his masters thesis in Oceanography which he received at the Naval Postgraduate School in 1971.

Breakthrough in Electric Power Research

A blast of hot gas roaring at 3,000 miles-per-hour down a 60-foot-long shock tunnel at General Electric's Space Sciences Laboratory has smashed the "efficiency barrier" that has stalled magnetohydrodynamic (MHD) electric power research for the past ten years.

The dramatic breakthrough came during a series of closed-cycle MHD tests when 20 percent of the heat generated in the shock tube was converted to 1,800-KW of electricity in hundredth-of-a-second bursts in a newly developed MHD generator.

The pioneering MHD research, sponsored jointly by General Electric and the Office of Naval Research (ONR), is an important step in exploring the promise of closed-cycle MHD power as a realistic energy option for the nation's utilities. The Navy is considering MHD applications for simplified, lightweight, and more efficient power and propulsion systems of the future.

Dr. Arthur M. Bueche, GE vice president for research and development, described the achievement of the 20 percent efficiency mark as "a major and exciting milestone in an intensive effort to tap the promise of MHD."

The highest efficiency attained thus far by open-cycle MHD is eight percent, which was in minute-long bursts in a system that produced some 32,000-KW and was about 20 times larger than the GE-ONR system. Reports from the Soviet Union indicate that 6,000-KW have been produced for day-long periods, but only at three percent conversion efficiencies.

According to industry figures, an estimated $150 to $200 million have been spent over the past 15 years on open-cycle MHD research, with about half in the Soviet Union.

Dr. Bueche noted that worldwide investment in closed-cycle MHD has totaled, by comparison, only about $20 million in the same time span, including some $4 million at General Electric, which has the nation's largest closed-cycle project under way. He pointed out that ONR has been a sponsor of GE's MHD research since 1961, and was one of the first organizations to recognize the potential of closed-cycle MHD.

"Our efforts have proved the scientific feasibility of closed-cycle MHD power generation and shown that it has many potential advantages over the open-cycle approach," Dr. Bueche said. "These closed-cycle advantages provide great opportunities for hastening the day when MHD may vastly improve the efficiency of power plants."

It has been estimated that power plants of the future may use an MHD system in conjunction with conventional turbine generators to achieve overall plant efficiencies approaching 60 percent, compared to today's optimum 40 percent.

Electric power is generated by MHD when a high-speed flow of ionized gas, a plasma hot enough to act as a gaseous conductor of electricity, is passed between poles of a magnet. In today's conventional power plants, by contrast, electricity is produced by passing a metal conductor through a magnetic field. (Figure 1)

Closed-cycle MHD differs from open-cycle in that an inert gas, such as argon, helium, or neon, replaces a combustible gas, and is recirculated rather than vented to the atmosphere. Moreover, operating temperatures of a closed-cycle system are one to two thousand degrees lower than those required for open-cycle, thereby substantially increasing the prospect of high reliability while reducing the need for new high-temperature materials.

With the success of GE's shock-tunnel studies on closed-cycle MHD, Dr. Leo Steg, manager of the company's Space Sciences Laboratory, Valley Forge, Pa., announced that a parallel development of the closed-cycle MHD project will involve construction of a system that will produce 15,000-KW in minute-long bursts, rather than the split-seconds achieved during the initial research.

He explained that this engineering phase calls for a coal-fired MHD test facility, which will use a heat exchanger to raise the temperature of the inert gas 2,500° to 3,000°F.

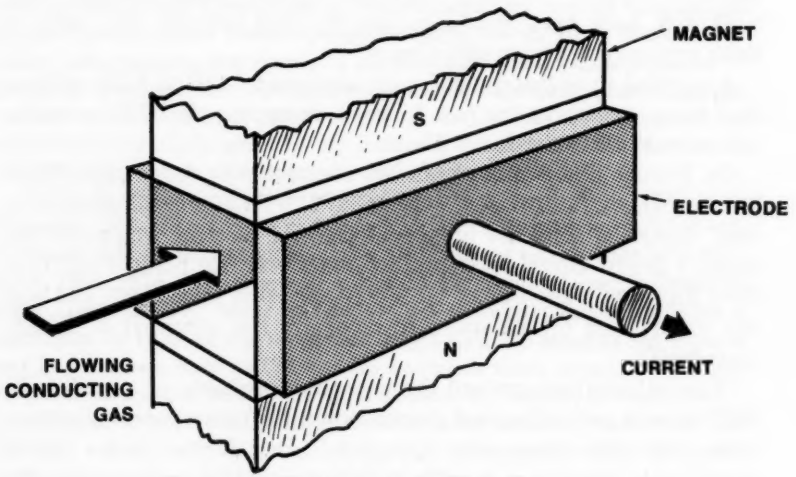

Figure 1 – How MHD works

"By building on the experience gained in the last ten years in our millisecond shock-tunnel work, we expect to attain our minute-long goal within the next three to four years," Dr. Steg added, "and then we plan to move into pilot plant construction and operation."

Work already has started on the engineering phase of the closed-cycle MHD project at GE's Space Sciences Laboratory under the sponsorship of the Electric Power Research Institute and the U.S. Office of Coal Research. Dr. Steg estimates that approximately $5 million will be needed during this phase, plus another $25 million to advance to pilot plant construction and operation by the early 1980s.

An open-cycle MHD plant with about the same efficiency as the GE system would cost more than $100 million and would have to be approximately ten times larger, Dr. Steg said.

The MHD program at GE's Space Sciences Laboratory is headed by Dr. Bert Zauderer, who first started the shock-tube approach in 1961 under ONR sponsorship to try to understand how an MHD generator works. The early system produced energy bursts lasting only half a millisecond.

Dr. Zauderer selected the shock-tube approach for initial efforts because it was the most convenient way to heat the argon gas, by forcing a shock wave down the tube, thus compressing and heating the gas behind it to a high temperature. The shock tube has also been used for studies related to high-speed missiles and space vehicles. By 1965, four percent heat-to-electric conversion efficiency was obtained and produced 20-KW for a millisecond, in a 50-cubic-inch generator.

The next milestone in Dr. Zauderer's project was reached in 1968 with 500-KW produced in a 1,200-cubic-inch generator at nine percent efficiency. This achievement surpassed the eight percent conversion mark reached by open-cycle researchers in 1964, a record that still stands for open-cycle MHD systems around the world.

In the last five years, MHD research team has: started using tungsten electrodes in the generator instead of copper; begun seeding the inert argon gas with cesium; enlarged the generator to 2,400 cubic inches; and tripled magnetic field strength to 27,000 gauss (the earth's magnetic field averages about one-half gauss).

During the engineering phase, the size of GE's generator will be increased five-fold, and coal, instead of a shock tube, will serve as the heat source. Dr. Zauderer expects that this machine will operate at a generator conversion efficiency of 30 percent, compared to the current 20 percent.

On the Naval Research Reserve

Improving Contract Negotiations

A new ONR procurement research program that may lead to improved methods of contract negotiations at the field level was begun in late May 1974 by CDR Kenneth Wallenius, NRRC 6-9, Athens, Georgia and Lt. Joseph I. McAdams, NRRC 6-18, Nashville Tennessee. The objective of the program was to develop a versatile computerized management information system (MIS) with specific emphasis on statistical applications.

The Naval Procurement (NAVPRO) Office, Bethpage, New York, was selected for running the initial test. Several members of NAVPRO's staff were familiar with computerized management services and by testing the system were able to tailor a program to meet their specific needs. An on-site computer which utilized a time-share terminal of the GSA Teleprocessing Service of Computer Sciences Corporation was employed.

The Naval Research Reserve Officers introduced a statistical procedure in contract negotiations which improved methods for processing proposals by using the basket sampling techniques developed by CDR Kenneth Wallenius, who is Professor of Mathematics at Clemson University. The significant benefits of this computerized technique are non-vulnerability to contractor padding, considerable man-power and cost savings, and increased reliability in the sampling process.

The Research Reserve Officers came to several conclusions from observing the MIS in action.

1. Trained personnel were needed so a programming specialist from Computer Sciences Corporation conducted training classes for one week.
2. The significant manpower and cost savings were obvious to all and were thought worth the necessary effort to obtain.
3. The requirements of NAVPRO will not involve high level programming or systems design. Thus after proper basic training, the staff should be able to design and maintain the system.
4. A full-time coordinator is essential to optimally utilize the computer system.
5. The six month trial period at Bethpage will be adequate to determine the success of this concept and the feasibility of similar projects.

NRRC 3-4 Teams Tackle Fleet Problems

Two teams in Rochester, New York, composed of members of NRRC 3-4 have been performing additional mobilization training by

working on real problems for Commander, Destroyer Development Group, Charleston, South Carolina. The effort began in early 1973 while DESDEVGRU was located in Newport, Rhode Island.

CDR Edward R. Schickler, USNR, and LCDR Lawrence S. Scott, USNR, have been developing a plan for measuring the operational effectiveness of the Rocket Launched Sonobuoy System which was under development by DESDEVGRU. This study to date has centered on systematically analyzing the many potential operational uses of this technology to determine the best payoffs for the task force commander.

Another team of six officers headed by LCDR Byron Buell, USNR, has been studying the command and control situation in the destroyer combat information center. Both of the projects fit the ONR mission objectives and have made extensive use of modern managerial science techniques. Response from COMDESDEVGRU to interim reports has been gratifying.

Army Award Given to CAPT Ernest Peterkin USNR

The Army's Meritorious Service Medal was recently awarded to Captain Ernest W. Peterkin NRRC 5-9, Washington, D.C. for his job while on active Navy reserve duty.

> The Meritorious Service Medal is awarded to Captain Ernest W. Peterkin, 577-54-1084, United States Naval Reserves for Meritorious service while serving in a special consultant and instructional capacity with the 1st Battalion (Reinforced), 3d Infantry (The Old Guard), Fort Myer, Virginia, from August 1972 to May 1974. Because of his reputation as the nation's foremost authority on colonial drill and ceremonies, Captain Peterkin was contacted to assist in the formation of a revolutionary war era unit within The Old Guard. He at once accepted the task to research and compile information on the unit in addition to his regular duties with the United States Navy. His primary mission was to research, instruct, and create an authentic reproduction of George Washington's Commander in Chief's Guard as it was known during the revolutionary war era. In May 1973 and again in April 1974 he was attached to The Old Guard for active Navy reserve duty. During these periods he worked tirelessly and further developed the manuals and training techniques to be used by the unit. The result of this total effort has been the authentic reproduction of the Commander in Chief's Guard. This company is expected to be used extensively in national becentennial activities. Because of the continued unselfish total effort by Captain Peterkin, this unit has come into being.

The actions by Captain Peterkin not only reflect great honor and credit upon him, but also on The Old Guard, the Department of the Army and the Department of the Navy, whose joint efforts made the project possible.

Does Diver Use More Air in Cold Water?

It has been generally felt that a diver uses more of his breathing air while operating in cold water, but there is no evidence from currently available information to determine the rate of increased consumption. However, there soon may be, as a result of tests being conducted at the Naval Coastal Systems Laboratory.

In a project under NSAP (Navy Science Assistance Program) sponsorship, engineer Max Lippitt of NCSL's diving and salvage department is conducting gas consumption tests with six military divers as subject at the Laboratory's hydrospace facility.

While data for computing gas consumption for different conditions of depth and work load are presented in the Navy Diving Manual and other sources, no information on the effects of water temperature and dive duration is currently available. Fleet units requested assistance through NSAP in their efforts to improve predictions of the amount of air divers need for various missions. NCSL was selected as the laboratory to obtain the data.

Following a preliminary physical examination, the divers, working as two-man teams, are properly suited with the operational wet suit they would normally be wearing during an underwater mission, and carry strapped to the body an electronic package that sends back to the monitors readings on heart function, respiration, and body temperature.

The divers, submerged in an 8- by 12-foot tank of water, undergo a series of tests while exposed to water temperatures of 40, 60, and 80 degrees Fahrenheit. They follow a planned schedule of rest, light and moderate work loads. Divers perform swimming tasks on a specially designed "swim ergometer," while continuous gas consumption and the physiological parameters are measured and recorded by equipment assembled and tested here at NCSL.

The six divers have been doing their "thing" in water for test periods of six hours each in the 8-foot-deep tank at the hydrospace facility. The bone-chilling effect of full submergence in nearly freezing water for prolonged periods with only the minimal protection of a wet suit must be experienced to comprehend fully the spirit and stamina exhibited by the divers participating in these tests. Adequate and reliable data could not be obtained without the outstanding performance and all-out effort shown by these men, according to Lippitt.

Although it is too early for any final conclusions, preliminary results show evidence that the diver does indeed consume more air while operating in cold water.

Research Notes

Fluorocarbons in Remote Areas of Globe

Naval Research Laboratory (NRL) scientists have compiled extensive evidence from surveys aboard ships and aircraft, that 20th Century man-made fluorocarbons are measurably present, not only in the atmospheres over populated lands, but in remote areas of the world, as well.

The highly biostable chemical (CCl_3F), widely used in air conditioners and refrigeration systems and as an aerosol propellant for spray paints, deodorants, hair sprays and insecticides, has apparently been travelling, invisible and unnoticed, on circulating air currents to virtually all portions of the globe.

The team of NRL scientists, headed by Drs. John Swinnerton and Peter Wilkniss, found persistent evidence of the presence of fluorocarbons while they were pursuing other research, seeking trace gases in the atmosphere to obtain a better understanding of the air-sea interface. Since then (the fall of 1972), they have been measuring the atmospheric fluorocarbons in remote areas of the Atlantic and Pacific Oceans.

Because the manufacture and production of fluorocarbons has been steadily increasing at a rate of about 9% a year, they feel it is important to know what the global distribution and concentration of this compound is, and what it will be within the next 10 to 20 years.

An average value of 61 parts per trillion (ppt) of the chemical compound was found for 200 air samples obtained on an NRL cruise from Los Angeles to the Antarctic in November and December of 1972.

These fluorocarbon concentrations, they said, agree with those of Dr. J. Lovelock of England, who found an average concentration of 52 ppt in the North and South Atlantic between November and March of 1971-72. Lovelock also reports an average concentration of 85 ± 5 ppt for samples taken in October of 1973 between 50°N and 18°N in the Atlantic Ocean.

The NRL scientists, in the spring of 1974, also collected 300 samples in the East Pacific Ocean between 20°N and 20°S; the average value was 81 ± 6 ppt. In addition, they measured 120 ± 18 ppt fluorocarbons in the Arctic air at 80°N in the vicinity of Spitsbergen in January 1974.

From this limited data, the scientists said, one can only speculate as to the steady buildup of fluorocarbons in the atmosphere. What is needed is a fixed station in a remote part of the world where these fluorocarbons can be measured continuously over long periods of time.

The NRL scientists, in addition to making atmospheric analyses, are also measuring fluorocarbons which are dissolved in the seawater. They have found fluorocarbons in the surface waters of the east equatorial Pacific to be near saturation level with respect to the atmospheric concentration. This too, is in agreement with Lovelock's finding in the Atlantic.

The NRL scientists found no evidence of fluorocarbons at ocean depths greater than 100 meters but are going to make more measurements in other areas

in the near future. From the limited number of measurements made of fluorocarbons in seawater, the scientists concluded that the concentration decreases rapidly below the thermocline.

A paper on the research, written by the principal investigators, was presented by Dr. Swinnerton to the annual meeting of the American Chemical Society in Atlantic City, N.J. on September 10. Dr. Swinnerton said the research is continuing with the next sampling of the gas to be taken on a mission from Norway to France.

Crosstie Memory Technique

A method of storing 1,000,000 bits of digital information per square inch in a very fast "crosstie" memory device appears to be possible as a result of research being conducted by the Naval Ordnance Laboratory with funding from the Office of Naval Research and the Naval Air Systems Command.

Computers require storage of a large amount of digital information. This may be stored in relatively inexpensive bulk memories such as magnetic tape. However, these provide slow access to the stored information. Semiconductor devices or core memories provide fast access, but are relatively expensive.

The search to fill the gap with a fast access, yet inexpensive method for storing information has included extensive development of the magnetic bubble memory and charge coupled devices. The bubble memory steps a cylindrical domain (the bubble) along a track. The presence of the bubble indicates a "one," or its absence a "zero." Conventional magnetic memories store information by pointing a magnetic region (domain) in one direction or another.

The crosstie memory depends on the magnetic structure in thin film magnetic materials. However, the information is not stored in the domains, but rather on the wall between two domains of antiparallel magnetization. The polarity of this Néel wall is locally changed from positive to negative by applying appropriate magnetic fields. The inverted section is bounded by a crosstie and a Bloch line. The presence or absence of this structure constitutes a one or a zero, as it moves down the wall.

This memory method allows the use of polycrystalline material, provides greater speed and density, and lowers the cost considerably. The 80 Ni-20 Fe permalloy films that are used are easily evaporated onto glass to a thickness of 370 Å.

The minimum distance between crossties is about 5 micrometers in a typical film decreasing with higher anisotropy. The domain walls can be placed about 25 micrometers or less apart. A density of one million bits per square inch is possible. Eventually about 70 million bits per square inch may be possible.

Inverted walls can be generated by placing a fine wire above the domain wall and applying a current pulse of proper polarity. A single overlay method of propagation is shown in Figure 1. The data are stable at zero applied field so no biasing magnets are required.

The time required to step one period is estimated to be 50 nsec, giving a data rate of 20 megabits/sec. Since such a method does not lend itself readily to

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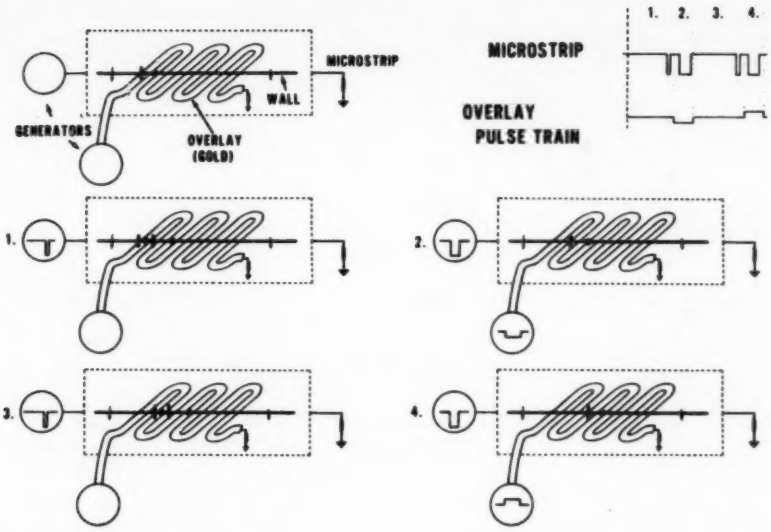

magnetic logic, the cost of detection must be low. On the other hand, the amount of money that can be spent on detection increases with the speed of the device. Detection can be accomplished by using magnetoresistance. Several methods of detection are under consideration.

Experimental shift registers have been constructed and data have been propagated. These experiments were done by observing the data visually using the Kerr effect.

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A blast of hot gas roaring at 3,000 miles-per-hour down this 60-foot-long shock tunnel has smashed the efficiency barrier that has stalled MHD electric power research for many years. *See page 25.*

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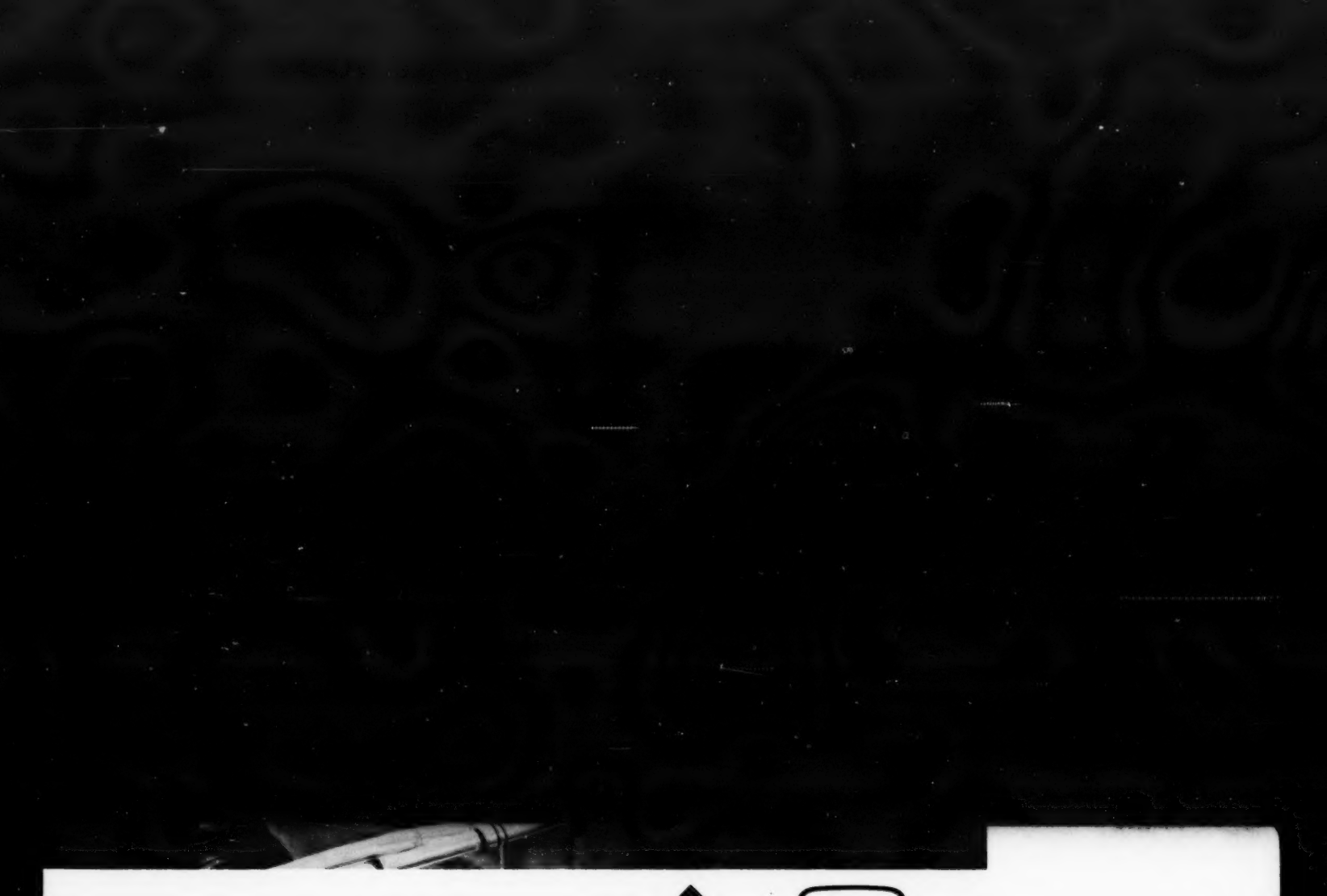
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